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THE SMALL OR MAGNETIC ANTENNA

Magnetic antennas are useable indoors or outdoors. They have only been in use by hams in recent years but are becoming popular for their adaptability to difficult circumstances. They are small compared with their wavelength so they deserve a chapter of their own.

"Small" means an antenna that is small compared to its wavelength. Any short wire loop can be tuned to frequency by the use of a tuning capacitor. Such antennas can be used for receiving. However, to use them as transmitting antennas means that allowance must be made for the much higher current flowing around them. Since the near-field of these antennas is mainly magnetic they are often called magnetic antennas.

Magnetic loops are intriguing. They can be far smaller than a wavelength. They must be carefully made, however, and one component - the tuning capacitor - must be of high quality. Nevertheless, anyone who takes the trouble to build a quality unit will have an antenna which, it is claimed, performs better than a dipole at low heights. Since it radiates the near-field magnetic component of the field, a loop is far less affected by absorption of the RF by nearby objects.

As a receiving antenna, where the efficiency is less important, a loop can be the antenna of choice. It is less likely to pick up interference because it responds to the magnetic field, not the electric. Most nearby interference is concentrated in the electric field.

This is truly an antenna worth looking at if space is at a premium, as it usually is in an attic. It can be disguised outdoors by setting it up in a dog kennel or small tool shed. A garage can contain two or three antennas on the sides or horizontally in the roof. But beware! The antennas would be seriously de-tuned when the car is in the garage. A small antenna of this type would be unnoticeable fixed to the back of a wooden chair on a balcony.

A magnetic antenna's efficiency is proportional to the area within its ring. Therefore, the best shape for a magnetic antenna is a circle. As the area of the shape diminishes, so does its efficiency. Octagons (97% compared to a circle) are easily made, using the 135 degree copper elbows from the plumbing counter at your hardware store. Squares (63% compared to a circle) using 90 degree elbows, are often used.

The circumference of the antenna is about 20% of a wavelength. Because of the very high currents flowing in them strict attention must be paid to the conductivity of the joints. That is another reason why a circle, bent from an uncut length of pipe, is preferred.

A magnetic transmitting antenna can be made from copper water pipe an inch in diameter. Some grades of pipe can be filled with sand and bent into a circle. If hard-drawn, and thus unbendable, it is formed into a square or octagon, using copper elbows at the corners and brazed or at least well soldered.

A variable capacitor is fitted at one corner or in the middle of one side. The capacitor has to resist high voltage so the plates are well apart from each other. The edges of the plates should be rounded.

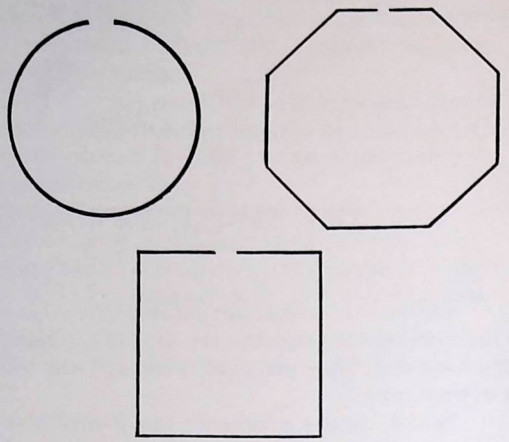

Figure 18 - *The three usual forms of a magnetic antenna. (A) is a circle of soft copper pipe, (B) an octagon of hard-drawn copper pipe with 135 degree sockets, (C) a square, made with 90 degree sockets. The gap at the top of each antenna is the location of the tuning capacitor.*

The signal is transferred to this loop by a small ring of heavy wire inside. Alternatively, the center conductor of the feedline is tapped to one side of the antenna at a point about 10% of the circumference from the feedpoint. Either of these is connected by a length of coax to the transmitter. The assembly is tuned by the loop capacitor. The tuning is extremely sharp.

Here are the details of a magnetic loop for the low bands, built by Robert, I1ARZ. It tunes from 14 to 30 MHz.

A 10 foot length of 7/8 inch or bigger copper pipe is bent into a circle having a diameter of about 40 inches. To do the bending, take a piece of one inch wood or thicker and cut a quarter-circle out of it, to a 40 inch diameter (20 inch radius). Screw this to a four foot square of 3/4 inch plywood. Screw a short piece of the one inch wood close to the quarter-circle as a stop to hold the pipe against the bend.

Fill the pipe with dry sand, tapping it as it is poured in to make sure there are no air spaces left inside, then plug the ends.

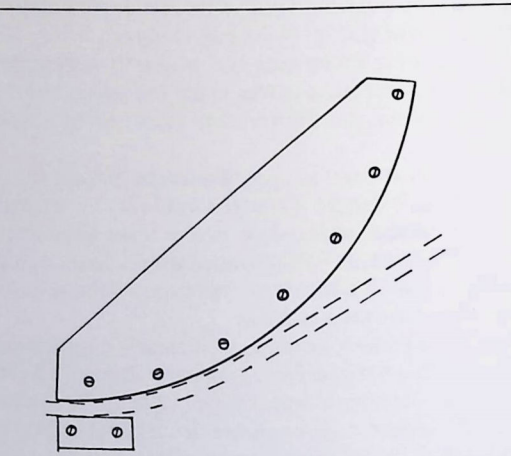

Figure 19 - *The plywood jig needed to bend copper pipe to a circle.*

Now trap one end of the pipe between the curve and the stop. Slowly and gently bend the pipe to the radius size. Before the pipe is bent the full quarter turn, relieve the pressure and slip the bent part of the pipe through the gap, ready to bend the next section. Keep the pipe flat against the backboard as you do this because the circle must be in one plane.

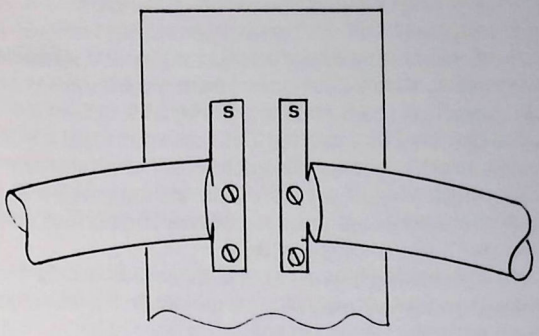

Figure 20 - *The ends of the pipe for any of the three shapes are partly cut through on the circumference, the ears so formed are flattened and used to bolt the pipe to a piece of plexiglas. The capacitor terminals are soldered at position (S).*

The ends of the pipe will now be fairly close together. Empty out the sand. Cut both ends along the length of the pipe for two inches and then to a diameter to leave a short half pipe at each end. This can be flattened to form a surface to which the capacitor can be soldered. The soldering must be well done to keep the resistance of the loop as low as possible. Drill a hole in each flat piece and use machine screws to secure it to a piece of quarter inch plexiglas.

The tuning capacitor must be of good quality. Best is a split-stator capacitor of 120pF per section, with a spacing of 0.03 inches or better. The edges of the vanes of a high-quality capacitor are rounded. Rounded edges do not discharge electrons into the air (corona or "St. Elmo's fire") as readily as sharp edges or points do.

Each end of the loop is soldered to a stator terminal of the capacitor. The entire capacitor is then equivalent to a 60pF variable capacitor connected across the end of the loop. It is best if tuned by a motor, allowing one's body to be kept away from the loop. The Herbach and Rademan catalog (P.O. Box 122,

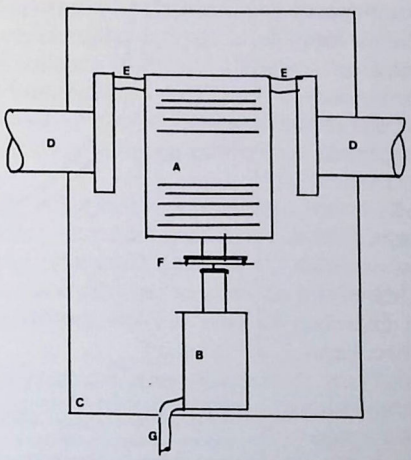

Figure 21 - *The ends of the pipe (D) are soldered to the capacitor (A) terminals at (E). The capacitor is driven by the motor (B) through the universal joint (F). The motor leads (G) are shielded and run straight down the antenna support.*

Bristol, PA 19007-0122) shows a high torque reversible motor turning at 0.6 rpm on 12 volts. The catalog number is TM92MTR1946.

A low speed and reversibility is essential because the tuning of a small loop is extremely sharp. Fit an insulating coupler between the motor and the capacitor.

If the loop is easily accessible from the shack, the motor can be replaced with a string drive. If you have ever dissected old radios you will know about these. The variable capacitor shaft carries a pulley. A length of cord goes around the pulley and one end of it is tied to a spring. The tuning control knob, which may be several feet away, carries another pulley. The cord goes around this and is tied to the other end of the spring, tightly enough to keep the spring extended. A pointer is fixed to the cord near the control knob. As the cord moves the pointer passes across a paper scale, marked to show the band tuning positions.

The tuning capacitor and its motor are bolted in place on the plexiglas. The plexiglas itself is supported on a mast (on a broomstick, for indoor use), being held on by pipe clamps, as is the loop. The motor feedline is of twin screened cable of the kind used in audio amplifiers. It is dressed down the mast and away.

RF energy is coupled into the loop by a secondary coupling loop. A single turn of heavy wire would do for transmitting, but it is usual to use a Faraday screen to make the antenna work better when receiving. This is a single turn of RG8 or RG13 coax, one-fifth to one-eighth of the main loop diameter, formed into a Faraday screen. The coax is formed into a loop of the chosen diameter and the vinyl cover is stripped from the

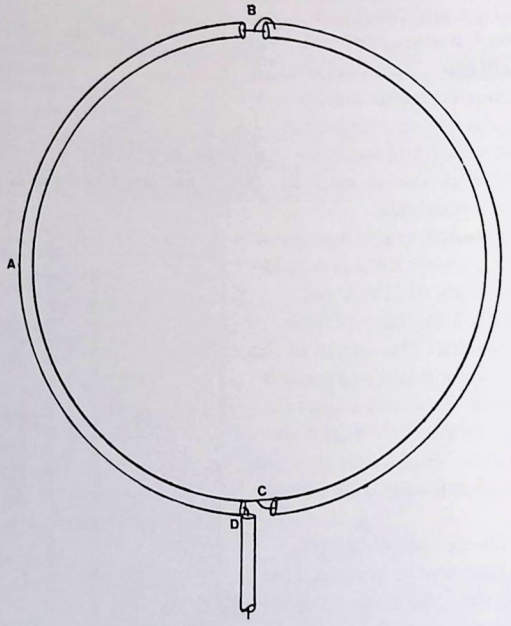

Figure 22 - *The shielded loop (A) to transfer the signal to and from the antenna. The loop is made from the end of the coax feedline. Measure off the length of line needed for the loop. At (D) the coax is sharply bent to start the loop, and the shield braid is exposed. The loop is cut half way around and the shielding is cut. The insulation is stripped from the inner conductor there, enough for a short lead to be soldered there and to the shield as shown. The coax continues around to (C), where the inner conductor is shorted to the shield and the inner conductor at (D). This loop is set up exactly in the plane of the main loop, opposite the capacitor, and can be moved slightly up and down to find the best SWR.*

end, and from where the end meets the feedline. They overlap about a half inch. Here the end inner conductor, the end screen braid and the braid near the feedline are all soldered together (see Figure 22).

Half-way around, cut off an inch of vinyl cover, cut the braid all the way around, strip the insulation from the inner conductor and solder it to only one side of the braid. The other side of the braid is trimmed back slightly to avoid shorts. The joint is bound with insulating tape. The feed end of the coax is fitted with a connector.

The loop is fixed to the mast by four hose clamps. At the top and bottom of the loop, one clamp that will fit the mast holds another one at right angles to fit the coax. The coupling loop is set exactly in the plane of the main loop. The feedline and the motor line must run down the mast three feet down from the loop to avoid unneeded coupling.

Set up a ground plane underneath the loop when it is in its final position. It need not be connected to the loop. A cross of household aluminum foil will do, as long as it will fit. If the loop is hidden away in a garage or garden shed, the ground is already there. Excite the loop at 18 MHz if you can, or else at 21 MHz, using the smallest amount of power that will move the SWR meter. Tune the loop capacitor for lowest SWR.

Now move the coupling loop up and down the mast inch by inch to see if the SWR can be improved. Keep the loops in the same plane. The size of the coupling loop can change the SWR too, so, if necessary, make another loop of a different diameter. I1ARZ found a loop two inches greater in diameter than that theoretically called for worked best for him.

The loop radiates in a figure eight pattern off the ends of the diameter of the loop, horizontally if the axis of the loop is vertical. If there is room the loop can be set up with a rotator to direct the signal in a chosen direction (actually two directions, on opposite sides of the loop). If headroom does not allow all of the seven feet needed to set the loop upright, it can be set sideways but, of course, then the rotation is not of much use.

If your interests are for even longer wavelengths and you have room for a bigger loop, I1ARZ has designed and built a square loop for 40, 80 and 160 meters, using the same plan. The sides are eight feet long. The material is 1 & 1/2 inch diameter light copper pipe. This is formed into a square with four copper elbows soldered (brazed is better) for highest conductivity. The job is done on a flat concrete floor to keep the elements in one plane.

The top of the square is sawn through at the half way point and connected there to a 7 to 1,000pF variable capacitor (preferably vacuum type). Again, be most careful to make good, high-conductivity joints. The capacitor must be rated at 7 kV for powers of 100 watts. Such a unit is expensive, but it is quite possible to make an air-spaced one from aluminum sheet, threaded rod, and plexiglas endplates. An 8 kV capacitor has 1/4 inch spaces between its plates.

The coupling loop is 20 inches in diameter, made as a Faraday screen, as above. Adjustment and feeding are the same, and naturally it is tuned on 40 meters. the bandwidth is narrow, especially on 160 meters.

Instead of coupling a loop, a coupling rod may be used. Very carefully solder the ground electrode of a coax connector to the inner conductor and take it along the loop for one-tenth of the circumference and solder it there. Adjust the spacing of this wire to get the lowest SWR.

Building and using a loop for use on only one band is worth consideration. The loop should be a little less than a quarter-wavelength in circumference. Since the tuning range is much smaller, good quality fixed capacitors can be used instead of a large capacity variable type. Use the best variable capacitor available to find the capacity needed at low power, and assemble fixed capacitors to give the same value. Or, cut a piece of RG8 to length. It has 100pF per meter. Two-sided copper-clad printed circuit board is another possibility. Measure the capacity of a full-sized piece of board and cut off what's needed to give the capacity you want.

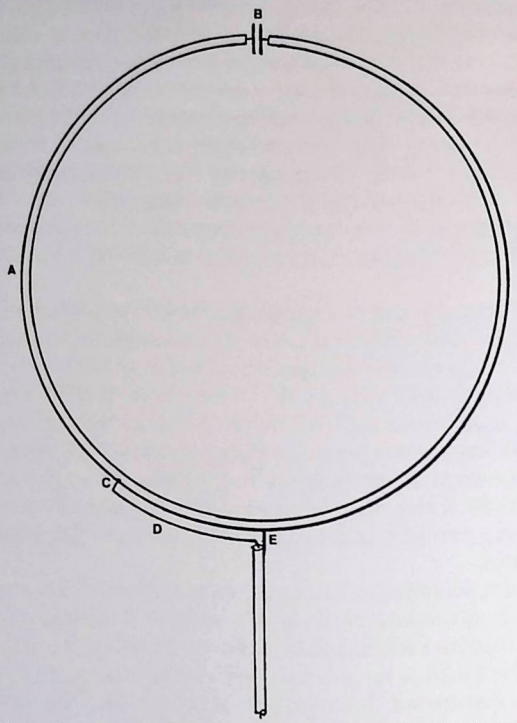

Figure 23 - *An alternative to the shielded loop. The coax feedline ends at (E). The outer braid is shorted to the loop at (E), exactly opposite the capacitor. The inner conductor is soldered to a length of heavy gauge wire, which is bent to follow the curve of the loop to the point (C), 10% of the circumference of the loop from (E), and soldered there. The spacing between the loop may be altered slightly to get the best SWR.*

Monoband Loop Dimensions

MHz	1.9	3.6	3.9	7.1	14.1	14.3	18	21	28.5
Side of sq. in meters	9	4.8	4.4	2.4	1.3	1.2	.95	.82	.6
inches	360	190	176	95	52	48	38	33	24
Diameter of circle in meters	11.5	6.1	5.6	3.0	1.8	1.5	1.2	1.0	.76
inches	460	244	224	120	72	60	48	40	30

Soldering copper pipe is a heavier job than most soldering work an amateur radio operator needs to do. A propane torch, flux-cored heavy gauge solder (this is sold for the purpose), medium sandpaper and a pair of heavy leather gloves are essential. Start by cleaning the end of the pipe or the inside of the elbow with sandpaper. Use a length of dowel to get the sandpaper right inside the elbow.

It is a good idea to make a jig of one by three inch lumber to hold the pipe in position when soldering. A "V" block at each end of a length of lumber rather shorter than the pipe to be used serves the purpose well.

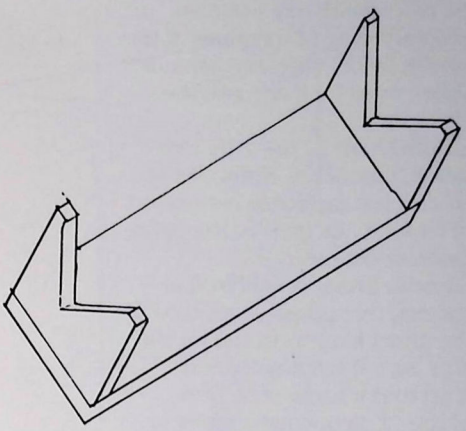

Figure 24 - *A jig to hold pipe steady when soldering it.*

Four meters or 13 feet of one inch pipe are needed for a 10 to 20 meter loop, along with four 90 degree elbows. This square loop will have sides 40 inches long. It is assembled and soldered, and one side is cut half way with a pipe cutter, taking out the short length of pipe to make space for the tuning capacitor. The ends are tinned and shaped as needed to fit the capacitor terminals.

First, cut the pipe to length. Then tin the cleaned ends. Tinning is the process of coating the copper with solder so that there won't be any unsoldered spots in the joint. Put on your gloves, lay the pipe in the jig and heat the cleaned end until the flame shows the slightest trace of green. Then remove the flame and touch the solder to the end. It should melt and spread neatly. Turn the pipe in the jig steadily to spread the solder evenly, adding more as needed. Do not heat and apply solder at the same time.

Leave the pipe. To tin the free end stick a spare bit of pipe in the bench vise and put the elbow on it. Heat this end in the flame and when the elbow is hot enough, melt some solder inside it. Then take the pipe out of the vise. Holding it in your gloved hand, turn the elbow so that the melted solder covers the inside. Reheat as needed.

Go back to the jib and heat the end of the pipe again until the solder melts. Keep the elbow in the flame, too. When all the solder is melted, put the elbow over the pipe end and turn the pipe to make sure the solder is evenly distributed. Reheat the joint and touch the point where the elbow ends with solder wire. Solder will be sucked into the joint. Now leave the assembly to cool.

Solder one elbow on each pipe. Then tin an end of one pipe and the elbow of another, and solder them together. Now there is an assembly of pipe-elbow-pipe-elbow. Make another. Prepare the free ends of each pair by tinning them. Tin the open elbows, put the assembly on a clean concrete floor and solder them together. This ensures that

the two sub-assemblies are flat. If the antenna is a square this will complete the soldering of the pipes. If the assembly is an octagon, further sub-assemblies must be made and finished flat.

If the shape of the attic roof demands it, one of the elbows can be omitted and the capacitor connected there. The feed line goes to the opposite elbow, of course.

A coax fitting is soldered to the pipe exactly opposite this cutout. Take the short length cut out for the capacitor, saw it lengthwise and open it so that it forms a "J." The hook of the "J" is opened slightly to fit snugly over the pipe. The stem of the "J" is drilled to fit the coax connector. The unit is then soldered into position.

A length of broomstick will serve as an upright. The capacitor is bolted to a sheet of plexiglas, which is, itself, bolted in position on the stick using U-bolts. The loop is then put in position and the top end fixed to the stick with two pipe clamps. The other end is soldered to the capacitor terminals.

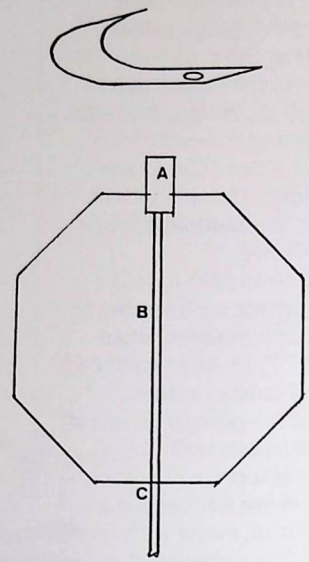

Figure 25A - *A short length of tube can be cut and opened out to form a "J" shape, drilled to fit the feed loop coax connector and then soldered to the main loop. Figure 25B - The general set up of a loop: capacitor (A) and supporting rod (B). The feed loop is secured at (C).*

The coupling loop is then made. This is a ring of coax, set up as a Faraday screen (see Figure 21). Alternatively, the coupling can be by a length of heavy wire or 1/4 inch soft copper pipe, soldered to the coax connector and to the ring (see Figure 23).

A garden, said the poet, is a lovesome thing. One delight in a garden is an arbor, what some call a pergola. This is a wooden archway, at least eight feet tall, and as wide as you wish, that plants and flowers can grow on. Erect one close to the shack and strengthen it with a ring antenna or two!

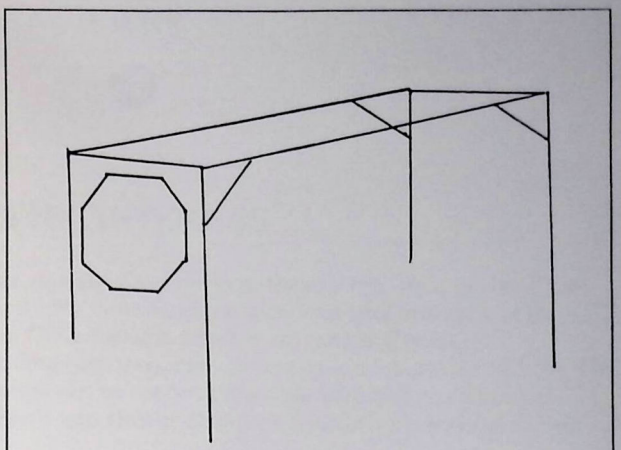

Figure 26 - *A pergola, or arbor, showing one possible position for a magnetic loop.*

Large diameter copper tubing is hard to bend, and probably expensive. G3PTN got around this by making the antenna out of two squares of RG8U coax, spaced three inches from each other. The square has eight foot sides. Inners and outers of the coax are soldered together at each pair of ends, and to the capacitor. This performs like a square of three inch diameter copper tubing with no soldered joints at the corners.

G3TWE modified this design slightly. He put in another pair of spreaders to turn the square into an octagon, which has higher efficiency than a square, though less so than a circle. He put the tuning capacitor at the bottom of the loop, the logical location since it is the heavier part. The coupling loop was two loops of coax, 36 inches in diameter and one inch apart. They were soldered screen to inner conductor and screened by pushing a bit of rubber hose over them, and wrapping it with aluminium foil.

He notes that the Faraday shield usually recommended is only of use for receiving. However, most people use the antenna for both receiving and transmitting anyway.